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Real-Time Vital Monitoring for Persons during Exercises — Solutions and Challenges —

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SUMMARY In the field of education such as elementary and middle schools, teachers want to take care of schoolchildren during physical trainings and after-school club activities. On the other hand, in the field of sports such as professional and national-level sports, physical or technical trainers want to manage the health, physical and physiological conditions of athletes during exercise trainings in the grounds. In this way, it is required to monitor vital signs for persons during exercises, however, there are several technical problems to be solved in its realization. In this paper, we present the importance and necessity of vital monitoring for persons during exercises, and to make it possible periodically, reliably and in real-time, we present the solutions which we have so far worked out and point out remaining technical challenges in terms of vital/physical sensing, wireless transmission and human interface.

key words: *vital sensing, wireless transmission, heart rate, body temperature, energy expenditure*

1. Introduction

In spring and summer times when a lot of sports games and sports days are held everywhere in Japan, heatstroke has become a fatal problem for schoolchildren during physical trainings and sports club activities in elementary and middle schools [1]. It has been often reported in Japan that tens of schoolchildren were taken to the hospital because of heatstroke during or just after physical training. It is partly because the temperature has drastically changed even within a day due the recent global warming and climate change, and partly because children can adjust to heat more slowly. In addition, teachers of such schools in Japan are busy and tired. It has been recently revealed that they work the most among those in OECD countries and spend more time on non-teaching work such as guidance in after-school, Saturdays' and Sundays' club activities [2]. Therefore, in the field of education, it is essential and eagerly required to take care of schoolchildren during exercises from the view-point of healthcare.

On the other hand, in the field of sports, physical training not according to the trainer's intuition or experience but to the athletes' scientific evidence such as vital and physical signs has proven to be effective. For example, in the Japan national rugby union team, whose world ranking is now tenth [3] (24 November 2015), athletes have been trained using their positions, velocities and accelerations [4]. In addition, in a Japan professional football team, athletes have been also trained using their vital signs as well as their positions [5]. Taking care of athletes during exercises is important from the view-point of not only effective physical/strategic training but also healthcare and injury/disease prevention. An unhappy incident is still fresh in our memory that Naoki Matsuda, a former defender of Japanese national football team, collapsed during training due to a cardiac arrest after finishing a 15-minute warmup run, and two days later he died at the age of 34 in 2011 [6].

As mentioned above, it is essential to monitor the health, physical and physiological conditions of persons during exercises periodically, reliably and in real-time. It is doubtless that information and communications technology (ICT) plays an important role in it, but ICT devices with real-time transmission capability have been used only in a limited part of professional sports; for a strategic purpose, a head coach can communicate with spotters in auditorium during an American football game by a wired or wireless system [7], and also a head coach can scout the skill of players during a volleyball game using the data gathered by a wireless system [8]. On the other hand, for amateur sports, there have been a lot of wearable devices on the market which can monitor vital signs, but their main function is not to send vital data in real-time but to store them once in the memory; after training, by checking the log, each person can understand his/her today's physical and health condition. Consequently, in realization of real-time vital monitoring system for persons during exercises, it is true that there are still several technical problems to be solved in terms of vital sensing, wireless transmission, data analysis and human interface.

In this paper, we discuss such technical problems and show the solutions which we have so far worked out. This paper is organized as follows. Sections 2 and 3 present technical problems and our solutions for them in vital/physical

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sensing and wireless transmission, respectively. Section 4 presents our solution for vital signs analysis and human interface. Section 5 points out several technical challenges and future directions. Finally, Sect. 6 concludes the paper.

2. Vital and Physical Sign Sensing

2.1 Body Temperature (BT)

When we exercise, our body needs more energy, so the metabolic rate increases accompanying more heat production. This is the reason why our body temperature (BT) increases and we sweat more to release the heat when we exercise. Therefore, it is reasonable to sense BT to understand the health and physiological conditions of our body during exercise [9].

When BT increases more than 40°C, heatstroke is likely to occur, which is life-threatening by damaging our brain and other vital organs. Therefore, even during exercise, BT should be below 40°C [9]. BT sensing is recommended at a deep part of our body such as the rectal or esophagus, but it is prohibitive during exercise. BT can be easily sensed at the surface of our body, and the easiest way is to contact a temperature sensor to it.

2.2 Heart Rate (HR)

When we exercise, our muscles need more oxygen. This is the reason why our heart rate (HR) increases to pump more oxygen from the blood in our lungs when we exercise. Therefore, it is reasonable to sense HR to understand the health and physiological conditions of our body during exercise [9].

The Karvonen formula determines our target HR training zone [10]. It requires our maximum heart rate (alternatively, our age) and resting heart rate in advance. According to our fitness goal, the target HR can be controlled by changing the value of training intensity. There are mainly two methods in HR sensing; one is electrocardiography (ECG) and the other is photoplethysmography (PPG). ECG measures the electrical activity of the heart by contacting the electrodes to the skin. On the other hand, PPG is based on opto-electronic technique, which illuminates the skin by a light emitting diode (LED) and measures the intensity of the light changed by the blood volume pulse (BVP) under the skin by a photo detector (PD). These two methods are simple and non-invasive so they seem suited for HR sensing during exercise, but they also have their own problems.

2.3 Oxygen Consumption (VO2)

The function of the lungs is gas exchange in the respiratory system; to extract oxygen from the air and transfer it into the blood (and to release carbon dioxide from the blood into the air). This is the reason why we breathe more when we exercise. Regarding the physical strength in terms of aerobic endurance, maximum oxygen consumption (VO2max) is widely used as the measure of cardiorespiratory fitness. Once VO2 is sensed, energy expenditure (EE) can be calculated from it [9], so it is reasonable to sense VO2 to understand the physical and physiological conditions of our body during exercise.

VO2 can be directly sensed using a VO2 meter, however, in this case, we need to wear a mouthpiece, so it is prohibitive during exercise. VO2 can be indirectly estimated by using acceleration data, which has been well investigated for several exercises such as slow and fast walking [11].

2.4 Suitable Positions of Vital Sensors

The electrodes of temperature sensor can be put at any positions of the body if sensing surface BT. On the other hand, the electrodes of ECG should be put at positions closer to the heart to sense stronger HR information, whereas an accelerometer should be put to a position closer to the body mass center to accurately sense acceleration due to gaits. If the three sensors are put at different positions of the body, they need to be connected by wire lines or wireless. Moreover, vital sensors need to meet strict requirements in terms of purity and durability, so in this sense, it is not preferable to install vital sensors into vest or t-shirt especially for healthcare application in elementary and middle schools. To avoid them, we finally decided to put a single node to the back waist position of a person jointly sensing surface BT, HR and acceleration thus VO2. Figure 1 shows a photo of the developed vital sensor node. The position is far from the heart, but HR sensing by means of ECG is possible.

Figure 2 shows the HR when a subject wearing an ECG-based HR sensor at his back waist position repeats running and standing-still alternatively. In the former half

Fig. 1 A photo of the vital sensor node.

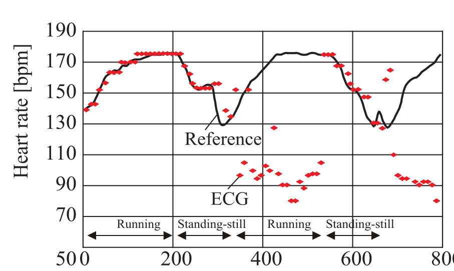


Fig. 2 HR sensed by ECG.

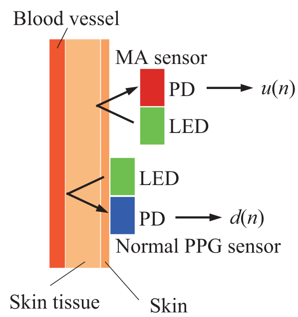


Fig. 3 Principle of the proposed MA canceling HR sensor.

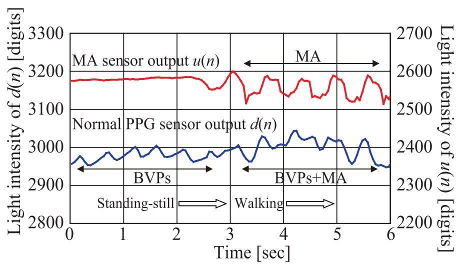


Fig. 4 Two outputs from the MA sensor and normal PPG sensor.

of the exercise, the ECG can correctly sense the HR, but in the latter half, it cannot any more. This is because the exercise gradually introduces sweat around the electrodes of the ECG and an electric current finally flows among them, resulting in the wrong HR. Due to this problem, we discontinued the use of ECG for HR sensing during exercise.

On the other hand, in HR sensing by means of PPG, the detected light intensity is changed by the BVP but it is also changed by the thickness variation of the skin tissue around the PPG sensor, which is called "motion artifact (MA)." Especially when a sensor wearer exercises vigorously, the frequency component of the MA overlaps with that of the HR, so the MA cannot be canceled by a linear filter such as band pass filter (BPF).

Figure 3 shows the principle of the MA canceling PPG-based HR sensor [12]. The proposed HR sensor is equipped with two LED/PDs. One LED/PD is used as a normal PPG HR sensor which contacts the skin; the light reaches a deeper part of the skin tissue and then is reflected by a blood vessel under it, so the PD output, which is denoted by $d(n)$, contains BVPs and MA. On the other hand, the other LED/PD is used as an MA sensor which does not contact the skin; the light is reflected at the surface or a shallow part of the skin tissue, so the PD output, which is denoted by $u(n)$, contains only MA. Figure 4 shows the two outputs from the MA sensor and normal PPG sensor, which are attached to a subject. In the former half, the BVPs are observed in $d(n)$ whereas nothing is observed in $u(n)$ since the subject stands still, but in the latter half, MA is observed in both $d(n)$ and $u(n)$ since he begins to walk. Then, applying the two PD outputs into an adaptive filter, we can simply extract the BVP component. Figure 5 shows the block diagram of an adaptive filter composed of a K-tap transversal filter with weights

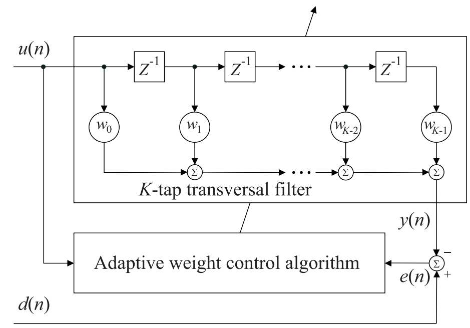
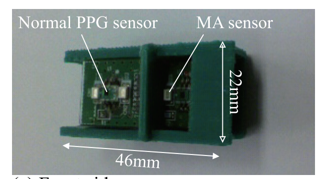
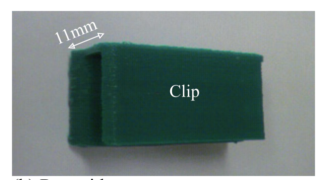


Fig. 5 Adaptive canceler.



(a) Front side



(b) Rear side

Fig. 6 Photos of the clip-type HR sensor node.

$w_0, w_1, \cdots, w_{K-1}$ and an adaptive weight control algorithm.

The MA canceling PPG-based HR sensor has two critical design parameters; one is the height of the MA sensor from the skin surface and the other is the distance between the MA sensor and normal PPG sensor. The effect of the two design parameters are examined in [13]. In addition, we confirmed that the proposed HR sensor works well for several exercises and motions such as standing-still, walking, fast-walking, running, jumping [12], [13] and deep breathing [14]. Furthermore, it should be noted that, defining the transversal filter output as $y(n)$, the weight control algorithm tries to make the error $e(n)$ between $d(n)$ and $y(n)$ be zero and BVP is obtained as "a residual error." Therefore, if the sampling rate is higher and the number of taps is larger, the canceler output contains weaker BVPs as it can better cancel not only the motion artifact but also the BVPs. This means that selection of the sampling rate and the number of taps is important.

We first developed the HR sensor node which is attached to a person with a belt, resulting in a high tightening pressure 20 ∼ 30 hPa and uncomfortability. Therefore, we then developed a HR sensor node which can be stresslessly attached to a person with a clip by hanging itself at the rim of undershorts [15]. Figure 6 shows the photos of the clip-type HR sensor node. We conducted an experiment where we put the developed HR sensor node at the back waist position of a subject and at the same a Holter monitor as a reference at the chest position of the subject. Figure 7

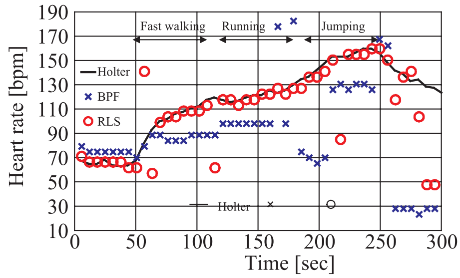


Fig. 7 Performance by the clip-type PPG-based HR sensor.

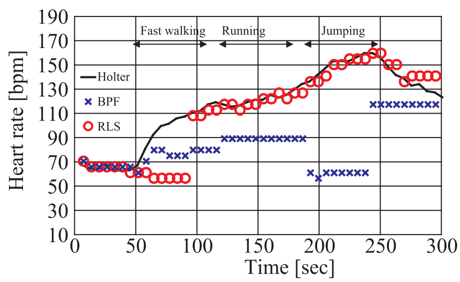


Fig. 8 Performance by the clip-type PPG-based HR sensor with the outlier rejection technique.

shows the performance by the proposed HR sensor when a subject makes a series of fast walking, running and jumping during the experiment. Note that the recursive least squares (RLS) algorithm is employed in the adaptive weight control. As compared to the case using the BPF, namely, without MA cancellation, the proposed HR sensor works well, outputting the HRs which are almost the same as those by the Holter monitor. However, sudden HR jumps and drops are sometimes observed for the proposed HR sensor, which are referred to as "outliers." The outliers occur because the low contact pressure 10 ~ 20 hPa cannot well stabilize the HR sensor on the skin surface so when the subject exercises, his HR sensor is likely not to contact the skin surface. However, taking into consideration the fact that the HR cannot suddenly change in reality, by setting an upward limit and a downward limit to the HR change, the outliers can be easily rejected. Figure 8 shows the performance by the proposed HR sensor with such an outlier rejection technique. The proposed MA canceling PPG-based HR sensor with the outlier rejection technique can work well for the series of exercises and make the HR sensing error less than 6% [15]. However, ouliers still remain in the range of 50 to 100 seconds, because relatively large two outliers successively occur in the range of 50 to 60 seconds. Therefore, a more effective outlier rejection technique is required, which may utilize another physical information such as acceleration data.

3. Wireless Transmission

If managers check the health, physical and physiological conditions of persons after exercise training, we can implement memory devices such as secure digital (SD) cards into vital sensors. On the other hand, if managers check them in the grounds, we need to transmit sensed vital and physical information from the persons to the managers periodically, reliably and in real-time, which can be realized only by wireless technology.

3.1 Suitable Sports Game to Evaluate the Capability of Wireless Transmission Scheme

As a sports game for evaluating the capability of a wireless transmission scheme, a group game composed of vigorous exercises is preferable. This is because if the wireless transmission scheme works well for the sports game, then it can work for other sports games and exercise trainings. Therefore, we selected a football game [17], because it is composed walking, running, sprint, jumping, sliding and so on.

3.2 Suitable Network Topology

Data collection from vital sensor nodes (VSNs) to a data collection node (DCN) is really an example of mobile ad hoc sensor network, so many networking protocols are applicable including pro-active and re-active routing techniques through sensor nodes [16]. When applying a pro-active routing through vital sensor nodes of athletes, they need to be always awake for forwarding vital data sensed at their own and other nodes, so it results in huge energy consumption. We once applied a pro-active routing technique in the 2.4 GHz band for a field experiment on the vital data collection for all players during a football game. However, before evaluating the energy consumption of VSN, we were faced with the fact in the game that we were not able to collect data reliably at all, since the network topology frequently, suddenly and drastically changed. Therefore, instead of the pro-active routing commonly used in ad hoc sensor networks, we took an approach of vital data broadcast and forwarding by placing data forwarding nodes (DFNs) around a football field. Note that the energy consumption of transceiver module is dominant in that of VSN. Therefore, according to the network configuration, the VSNs, whose batteries are severely limited, can save energy consumption by periodically powering-off their transceiver modules except for sending sensed data to DFNs. On the other hand, the DFNs, which are equipped with larger batteries, can forward the received data to a DCN directly or indirectly through other DFNs. Figure 9 shows the field layout for evaluating wireless transmission capability during a football game where six DFNs are placed around the field [17].

3.3 Suitable Wireless Transmission Scheme

3.3.1 2.4 GHz Frequency Band

Unlicensed communication devices can be used in the 2.4 GHz industrial, scientific and medical (ISM) band (2.4–2.4835 GHz) commonly all over the world, and there are many inexpensive transceiver modules and chips available on the market, such as certified by WiFi [18], Zigbee [19]

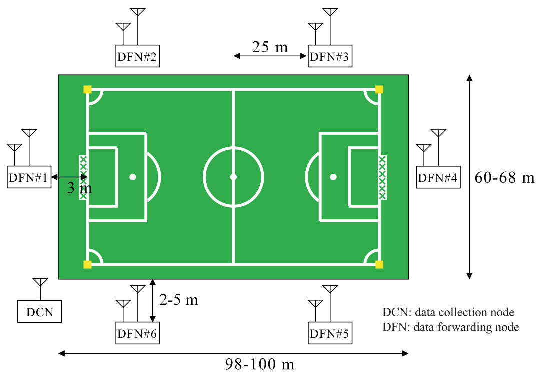


Fig. 9 Field layout for evaluating wireless transmission capability during a football game.

(a) A DFN (b) Players with VSNs

Fig. 10 Photos of a football game: a DFN (a) and players with VSNs (b).

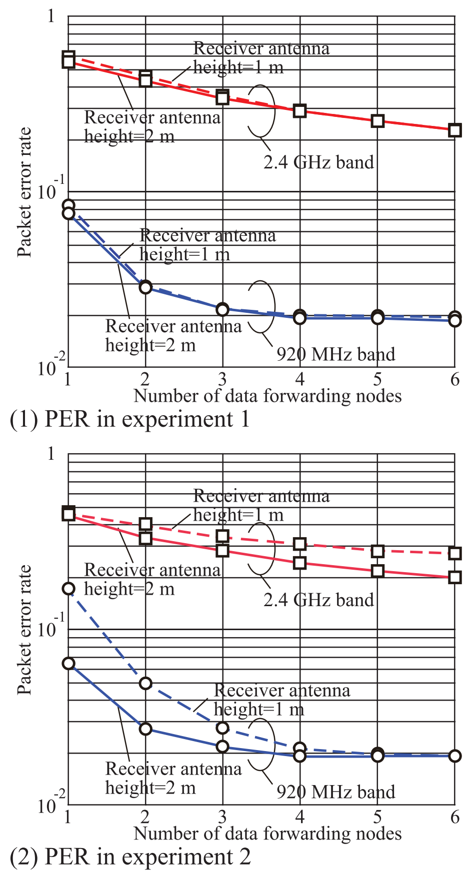


Fig. 11 PERs at the DFNs in football games.

and Bluetooth [20]. For the devices operating in the frequency band, the advantage is their high data transmission rate of up to several tens of Megabits per second (Mbps), but the major disadvantages are their short transmission range and vulnerability for fading and blocking.

3.3.2 920 MHz Frequency Band

Unlicensed communication devices can be also used in the 920 MHz band (920.5–928.1 MHz) but now they can operate only in limited regions such as North America and Japan. Contrary to the 2.4 GHz band, for the devices operating in the 920 MHz band, the disadvantage is their low data transmission rate allowed to be up to several hundreds of kilobits per second (kbps) [21], but the advantages are their long transmission range and invulnerability against fading and blocking.

3.3.3 Field Experiments

As mentioned above, the wireless communication devices in the 2.4 GHz and the 920 MHz bands have their own different pros and cons, so we decided to conduct field experiments to compare their wireless transmission capabilities in 90-minute games. In each field experiment, we put VSNs to the back waist positions of twenty two football players, whereas we placed six DFNs around a football field [17]. Figure 10 shows photos of a DFN and players with VSNs.

The VSNs transmitted packets at the same timings with transmission interval of ten seconds in the two frequency bands, and we collected the packets transmitted from all the players and received at the DFNs and the DCN. Figure 11 shows the PERs in the broadcast channel. We conducted six field experiments under the same condition, and the figure shows the results obtained in experiments 1 and 2. Here, note that a packet error occurs only when no DFNs can correctly receive the packet. For the communication device in the 2.4 GHz band, even if we use six data forwarding nodes, the PER cannot be less than 20%, whereas for the communication device in the 920 MHz band, using only two or three data forwarding nodes, the PER can be less than 3% [17]. Regarding the receiver antenna height, the PER setting the antenna height to 2 meters is lower than that setting the antenna height to 1 meter.

On the other hand, for the vital data forwarding, there are two methods to be designed, such as a single-hop direct forwarding from DFNs to a DCN with the 920 MHz band and a multiple-hop indirect forwarding from DFNs through DFNs to a DCN with the 2.4 GHz band [22]. Figure 12 shows the PER in the forwarding channel, which was obtained in experiment 5. The state of the forwarding channel was rather static as compared to that of the broadcast channel, so in this experiment, there was no difference in the PER between the 920 MHz direct forwarding and 2.4 GHz indirect forwarding. It should be also noted that, compar-

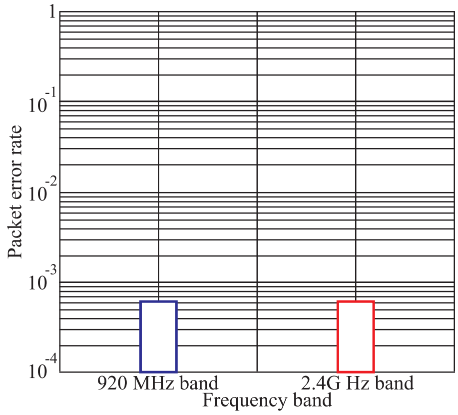
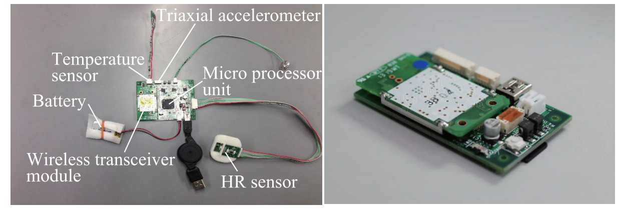


Fig. 12 PER at the DCN in a football game.



(a) First prototype (b) Second prototype (without sensors)

Fig. 13 Photos of the VSNs: the first prototype (a) and second prototype (b).

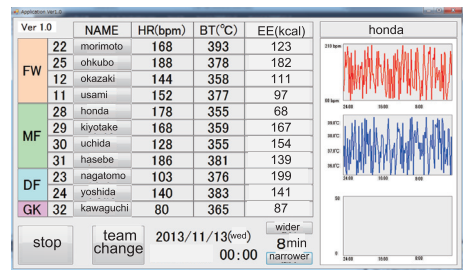


Fig. 14 A display image of the DCN.

ing the results in Figures 11 and 12, the packet error in the broadcast channel is dominant [22].

4. Vital and Physical Data Analysis and Human Interface

We have developed a system/application which can collect vital and physical information such as BT, HR and EE from several tens of persons putting on VSNs through several DFNs and display them at a DCN (note PC) [23]–[25]. Figure 13 shows photos of the first and second prototype VSNs. The capacity and weight of the first prototype VSN were 93 cc (8.5 cm × 5.5 cm × 2.0 cm) and 72 g, respectively, and as compared to it, the second prototype VSN has half the capacity (46 cc) and the same weight (72 g).

Figure 14 shows a display image of the DCN for football application. We have developed the human interface by interviewing several professional and amateur coaches of football, who are not so familiar with using ICT devices. In the display, a trainer can confirm current BT, HR and EE values for all trainees and check them for any trainee in more detail when clicking his/her name. The following items have not been implemented but they can be easily realizable by software programming:

- To prevent heatstroke, the BT limit such as 40°C can be pre-set. For example, when the BT reaches the limit value for a trainee, the trainer can notice it by alarm and advise him/her to take a rest or drink water.
- To improve physical fitness, an individual's target HR training zone can be pre-set. For example, when the HR goes out of the zone for a trainee, the trainer can advise him/her to take a rest and drink water.
- To estimate fatigue, an individual's maximally allowable EE can be pre-set. VO2 is also estimated, so according to the history of his/her daily, weekly and monthly maximally achievable VO2 for a given training menu, his/her physical fitness can be also evaluated.

In addition, comparing the degrees of an individual's physical strength promotion for a series of different exercise trainings, we can evaluate an exercise training menu most effective for the individual. Moreover, comparing the degrees of physical strength promotions obtained from a number of trainees among different training menus, we can evaluate the potential of each exercise training menu.

5. Technical Challenges

5.1 Vital and Physical Sign Sensing

For the HR sensing, the proposed MA canceling PPG-based sensor with the outlier rejection technique works well for vigorous exercises, but the power consumption of PPG is high, so reduction of the power consumption not only in optical component but also in digital signal processing is one technically challenging issue. In addition to it, as mentioned in 2.1 and it is connected to the heat stress index explained in the following, to estimate the human stress due to heat, namely, prevent heatstroke, not surface BT but deep BT needs to be sensed. Therefore, how we can estimate deep BT from surface BT, in other words, how we can screen for heatstroke and other diseases just by sensing surface BT during exercise is another technically challenging issue.

Furthermore, Fig. 15 shows a photo of the experiment on VO2 measurement, where a subject wearing a VO2 meter and a triaxial accelerometer at his waist position is running on a treadmill. Figure 16 compares the VO2 directly measured by the VO2 meter with that estimated by the triaxial accelerometer, changing the speed of the treadmill from 0 km/h to 16 km/h. Note that the data were obtained for five different subjects and the equation in [11] is used to estimate the VO2 from the triaxial accelerometer data. From the low to middle VO2 values, the estimated VO2 values agree well with the measured VO2 values, but the high VO2 values are over-estimated. This is because the equation in

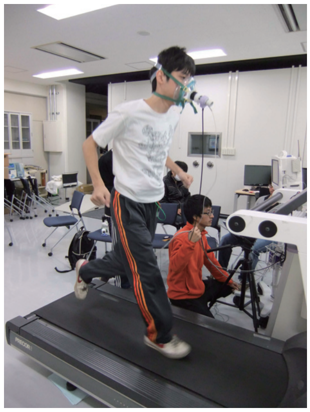


Fig. 15 A photo of an experiment on VO2 measurement.

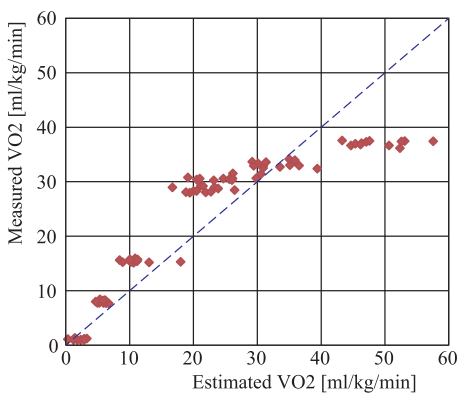


Fig. 16 Relationship between the measured and estimated VO2.

[11] is originally developed only for exercises where either of the two legs of an accelerometer wearer always touches the ground. In the high VO2 region, the subject's running produces the time periods when neither of his legs touches the ground, resulting in the overestimate of VO2. According to the best of the authors' knowledge, there is no work on VO2 estimation by means of triaxial accelerometer for vigorous exercises such as running and sprint, so development of an equation connecting VO2 and triaxial accelerometer data which is valid for such vigorous exercises is a technically and physiologically challenging issue.

Showing an individual's vital information by nuerical values such as HR, BT and EE in the display is important, but it may be hard for ordinary people who are not so familiar with sports physiology and healthcare to understand their meanings. Regarding the stress due to heat, the heat stress index (HSI) has been developed, which shows the degree of the stress in the range of 0 to 5. To evaluate heat stress, the environmental stress index (ESI) is defined as [27]

$$\mathrm{ESI} = 0.63AT - 0.03RH + 0.002SR + 0.0054(AT \times RH) - \frac{0.073}{0.1 + SR} \quad (1)$$

where AT, RH and SR are the air temperature, relative humidity and solar radiation, respectively, which are easily measurable by adequate sensors. On the other hand, the personal stress index (PSI) is defined as [26]

$$\mathrm{PSI} = 5\frac{BT_{deep}(t) - BT_{deep}(0)}{39.5 - BT_{deep}(0)} + 5\frac{HR(t) - HR(0)}{180 - HR(0)} \quad (2)$$

where BT_{deep} and HR are the deep body temperature and heart rate, respectively, and t and 0 are the time instants at t and 0 (initial), respectively. Note here again that the PSI is calculated with not surface BT but deep BT. Therefore, estimation of deep BT by vital and physical data sensable using wearable ICT devices is one technically and physiologically challenging issue. Furthermore, combination of (1) and (2) means to accommodate an individual's heart rate and temperature as well as environmental variations in temperature, humidity and radiation for evaluating the HSI for the individual. Therefore, how to combine them in the range of 0 to 5 is another technically and physiologically challenging issue.

5.2 Wireless Transmission

We have been successful in development of a vital collection system for persons during exercises, but the number of accommodatable persons is limited up to 100. Imagine that we apply a vital collection system for schoolchildren of a large size elementary school in a sports day. The number of schoolchildren will reach 1,000 and the density will be 1 person$/m^2$. We have evaluated the packet error rate in the scenario of a sports day and have confirmed that the simple broadcast/forwarding network configuration does not work well [28]. Therefore, developing a new wireless transmission scheme together with network topology is a technically challenging issue. Furthermore, in order to accommodate the number of nodes with the above order, the reduction in data to be transmitted over the wireless channel is necessary besides the improvement of transmission efficiency. Here, a key question is how to achieve sufficient reduction without losing the quality and freshness of vital data, which requires us to develop transmission schemes considering diverse features of vital information.

5.3 Vital and Physical Data Analysis and Human Interface

Finally, Fig. 17 shows an application image of real-time vital monitoring system. Assume that you are a teacher of an elementary school and are taking care of schoolchildren during physical training. You put on a smart glass, so when you see a certain schoolchild, the glass automatically can show you his/her name and health condition not only in numerical values but also colors. Realization of such a system is very challenging, interesting and fantastic, requiring much more techniques such as augmented reality (AR) and person identification with the help of face recognition and position information provided by global positioning system (GPS), together with vital/physical sensing and wireless transmission techniques.

In addition, the collected vital and physical data during exercises can be big data, but in this case, context data such

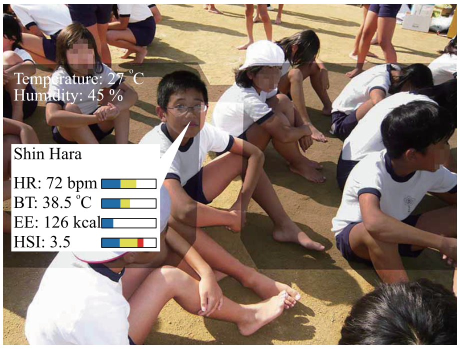


Fig. 17 Application image.

as the time, place, temperature and humidity of the day and the kinds of training menus, which should be synchronized to the time series of the data, should be memorized and included into the big data. Furthermore, to make the big data really useful for the medical and healthcare purposes, for example, by finding a useful knowledge out of the data by means of machine learning, their secondary use is essential. In this case, the method of anonymity, where to store the data and who to manage the encryption key must be technically, politically and regulationally the most challenging issues.

6. Conclusions

In this paper, we have addressed several problems to be solved in realization of vital collection for persons during exercises periodically, reliably and in real-time, and have presented the solutions which we have worked out and the technical challenges which we need to tackle in the future.

Real-time vital collection system for persons during exercises is really important from the view-points of healthcare and sports training according to the person's scientific evidence. However, now we are in the year of 2016, so we only have a little time left by welcoming to Japan the Rugby World Cup in 2019 [29], the Olympic & Paralympic Games in 2020 [30], and the World Masters Athletics Championships in 2021 [31]

Furthermore, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) officially decided in 2013 to export the unique physical education of Japan to 15 developing countries by the year of 2020 [32]. Exporting not only the software of the curriculum, program and menu but also the hardware of the real-time vital collection system for schoolchildren during physical training really enhances the international competitiveness of Japan. Our challenge towards its realization is still going on.

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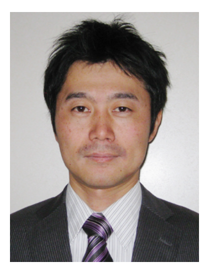

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